A STUDY OF THE EFFECTS OF ROW WIDTH AND PLANT SPACING IN DWARF GRAIN SORGHUMS

by

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INTRODUCTION

Sorghum has become an increasingly important crop in the United States since it was first introduced in 1853.

Grain sorghum is a substitute for corn in the Great Plains region where the crop is much better able to meet the severe climate. The drought-enduring qualities of the sorghum crops have given them particular interest in regions of limited and uncertain rainfall. In more recent years its immunity to the Southwestern corn borer has also helped to increase the sorghum acreage in certain areas.

The ability of sorghum to produce a crop under dry, hot conditions may be due to a number of factors: (1) ability to remain dormant during drought and then resume growth, (2) high resistance to desiccation, (3) low transpiration ratio, (4) large number of fibrous roots, and (5) ability to produce a crop from tillers and branches that develop after rain comes.

Sorghums are adapted to a wide variety of soils found in the Great Plains. However, they do best on land that is fertile, friable, well drained, and level to gently rolling. Sorghums will tolerate considerable quantities of alkali or soil salts. Sorghum is a hot weather crop and may do quite poorly in cool seasons, especially when frosts are early.

The sorghum crop is planted for various reasons: relatively free of serious diseases and insect pests, well suited as a late planted crop, as a catch crop, or as a full season crop under limited moisture conditions. It is an excellent catch crop

on land where winter wheat has winter killed or has been abandoned for various reasons. Sorghum also is an ideal substitute crop for some of the land directed from wheat under an acreage control program.

Sorghum can also serve as a supplementary crop to be grown with wheat. It is especially desirable if the same machinery can be used for both wheat and sorghum production.

This is one of the advantages of the dwarf type of grain sorghum, it can be harvested in the field with a combine.

When the dwarf varieties were first introduced they were grown under the same production methods as corn, i.e., in the usual 40 or 42 inch rows where weeds were controlled by cultivation.

In order to find a system of production where the dwarf types were better adapted, the plan of planting in 20 or 21 inch rows was tried. The narrow rows have shown a decided yield advantage over the wider row spacings in work done at Manhattan, Kansas, over a period of years.

This thesis is a report of a study made in 1956 of some of the factors concerned in the higher yields of dwarf grain sorghum from narrow rows.

REVIEW OF LITERATURE

The literature review in this report is divided into sections which include some of the various factors affecting the production of grain sorghums. Reviews of previous works are included under the following headings: (a) cultural practices, (b) effect of row width and plant spacing, (c) evaporative power of the air and transpiration, (d) light, and (e) temperature.

Cultural Practices

According to Martin, et al. (16), good seedbed preparation is important for grain sorghums for several reasons, particularly in securing stands, controlling weeds and conserving moisture. Working the ground mellows and warms the soil, which aids in securing better stands. "Ample tillage prior to planting usually will repay the labor involved." Fewer cultivations after planting are necessary if the weeds are kept well under control during the spring prior to planting.

Laude and Swanson (7) stated that by proper seedbed preparation sorghum yields could be increased from 25 to 50 percent. They believed that a thorough preparation of the seedbed was of primary importance.

It was reported by Brandon, et al. (1), that preparing the seedbed was important to store moisture, destroy weeds, and mellow and warm the soil. Warming the soil is important because sorghum germinates poorly in cold soils. A weed-free seedbed is essential, since sorghum seedlings are small and grow slowly for several weeks after emerging from the soil.

Martin and Leonard (15) concluded that a warm, mellow seedbed is essential to good seed germination and that weed control before planting is very desirable.

Spring tillage is important for yields regardless of the tillage given the previous summer, fall or winter according to Ross and Laude (23). Spring tillage kills weeds, incorporates plant residue, improves the physical condition of the soil and hastens warming of the seedbed.

Most investigators agree that the only value of post planting cultivation is to control weeds and possibly to allow water to enter the soil more freely.

Kiesselbach, et al. (6), stated that the rate of seeding depends on germination, varietal differences in size of seed and plants, and manner of planting, whether in rows or close drills. Germination of sorghum seed is commonly not high and no seed should be planted without testing. Ordinarily about 50 percent less germination can be expected in the field than is obtained in germination tests.

The most satisfactory rate for seeding grain sorghums depends on several factors according to Martin, et al. (16). Assuming good seed, suitable preparation of the ground and timely planting, the variety and the supply of moisture likely to be available are the most important factors to consider. Thinner planting and less seed is required for varieties that sucker freely.

Effect of Row Width and Plant Spacing on Sorghum and Other Crops

Martin, et al. (17), reported that the yield of grain sorghums depends to a large extent on cultural practices but that optimum spacing of the plants and seeding at the proper time were also important factors.

Tingey (28) found that the number of plants per unit area was the most important factor affecting yield of rubber and shrub from guayule planted directly in the field. He compared rows 14 and 28 inches wide with the same number of plants per acre.

In the spacing experiments with corn, Bryan, et al. (2), found that a spacing of 21 x 21 inches gave higher yields than a 42 x 42 spacing in two years out of four. In the other two years the difference was nonsignificant. In general, they concluded that within comparisons involving the same number of plants per acre, minor variations in spacing had little effect on yield.

Hastings (4) found that spacing the plants closer in the row resulted in less branching and tillering but gave higher yields of milo in Texas. The thicker seeding also produced plots that were more uniform in their date of maturity and the ripening period was shorter.

Under irrigation in Washington, Nelson (21) reported that with row widths of 24, 30, and 36 inches and corresponding plant populations of 228,000, 150,000, and 72,000 plants per acre, there was no significant differences in yield between spacings or varieties.

At Woodward, Oklahoma, it was found by Sieglinger (25) that varieties which sucker profusely produce similar yields of grain when the distance between plants in the row varies from six to 30 inches. Varieties which produce few suckers showed progressive reductions in yield for every successive increase in the distance between plants from six to 12 inches up to 30 inches.

Painter and Leamer (22) reported that plant spacings of four inches in 36-inch rows gave an average response of five bushels over spacings of nine inches in the same row widths.

Martin (14) concluded that the yields of fields of grain sorghums are more closely correlated with the number of heads per acre than with the size of head, or weight of grain per head. The correlation between the number of heads per acre and both the weight per bushel of grain and the average size of heads is either negative or not significant.

Karper, et al. (5), found that the size of head in both milo and kafir increased almost directly as the space between plants increased, but there was no difference in the shelling percentage of the heads produced.

Evaporative Power of the Air and Transpiration

Miller (20) stated that two main environmental factors affect the evaporation of water. They are the evaporative power of the impinging solar radiation and evaporative power of the air, the influence of air temperature, air humidity, and air movement.

Martin (18) described a linear relationship between the transpiration rate in *Helianthus* and light intensity. The fraction of

transpiration due to direct effect of radiation varied from 38 to 81 percent, depending upon the evaporating power of the air.

Along with several other factors, intensity of radiation has been found to be of great importance in controlling the rate of evaporation from the shoot and, hence the rate of water absorption by roots, Burkholder (3).

Locke and Mathews (10) stated that evaporation is a result of the combined effect of temperature, wind velocity, and humidity. An indirect effect of wind velocity is increased evaporation.

Livingston (9) believed that a spherical evaporating surface was the only one that gave proper exposure to both wind and radiation at all times.

Wilkins (33) and Stickler (27), using Livingston atmometers, measured the evaporative power of the air in dwarf grain sorghum plots. They found that the water lost was considerably greater in 40-inch rows than in 20-inch rows.

Martin and Clements (19), in their work with Helianthus annus, found that with an increase in wind velocity up to 16 miles an hour, evaporation was increased 138 percent. There was an initial increase in rate of water loss with an increase in wind velocity. Wind affected the transpiration rate to a greater extent in the daytime than at night.

Light

Shirley (24), in studies on the influence of light intensity and quality upon the growth of plants, found that both height and leaf area attained maximum development at low intensities. Height

increased with decreasing light. The leaf structure tended to become more compact with increasing light, i.e. leaf thickness tended to increase. An increase in light intensity also resulted in an increase in root growth. The growth rate of the plant, as measured by increase in dry matter, was proportional to light intensity, up to 20 to 30 percent of full sunlight. Plant maturity was delayed by low light intensities.

Karper, et al. (5), stated that the amount of tillering was influenced by the amount of sunlight striking the plant. Shading appeared to have a marked influence on tillering and was demonstrated by spacing plants the same distance apart in rows but varying the row width.

Livingston (9) declared that light conditions are effective only above the soil.

The important functions of light were summarized by Burkholder (3) as being photosynthesis, chlorophyll formation, transpiration, absorption and use of solutes, permeability, protoplasmic movement, photoperiodic stimulation, acidity, stomatal movement, and phototropism.

Temperature

It has been estimated by Vinall, et al. (31), that the optimum temperature for growth of sorghum is about 92° F., and that sorghum makes only indifferent growth at temperatures lower than 60° F. Vinall and Reed (30) reported that above the optimum temperature, growth is retarded by further increases in temperatures until the maximum is reached, when growth ceases entirely.

Continued exposure to the maximum temperature will cause death.

Martin (13) reported that sorghum plants have survived repeated exposure to air temperatures of 120 to 140 degrees in a greenhouse in summer. Observations suggest, however, that temperatures much above 100 degrees are somewhat detrimental, especially when plants are approaching heading stage.

Sorghums are primarily a warm weather crop. They are very sensitive to low temperatures during germination and growth. Leonard, et al. (8), stated that the minimum temperature for germination of sorghum seeds varies from 45° to 50° F., but the minimum temperature for later plant growth is approximately 60 degrees. Best yields are usually obtained where the mean July temperature is between 80 and 85 degrees.

Lyon and Buckman (12) believe that vegetative cover influences the amount of solar energy received at the soil, and therefore that the vegetative cover is an important factor in affecting soil temperature.

MATERIALS AND METHODS

The sorghum spacing experiment in 1956 was conducted in field E-2 of the Kansas State Agricultural Experiment Station agronomy farm located at Manhattan, Kansas. The preceding crop grown on the field was sorghum (1955 sorghum spacing experiment).

Seedbed preparation began with the plowing of the field in the spring. This was later followed by a single discing prior to the date of planting. Final seedbed preparation was accomplished by a single discing and then cross harrowing on the date

of planting. This final tillage, as well as the previous discing, destroyed a crop of weeds. The seedbed was in excellent physical condition at the time of planting but due to conditions the previous year, the soil was heavily infested with pigweed (Amaranthus spp.) seed. There was sufficient surface soil moisture for germination and emergence of the sorghum. However, a heavy shower immediately following planting resulted in some crusting of the surface soil and prevented emergence of some plants.

Although the sorghum plants were not able to emerge as quickly as normal, pigweeds germinated and emerged very rapidly and were ahead of the sorghum in growth before the sorghum could provide any shade to aid in their control. In order to prevent the weeds from completely dominating the experiment, the entire field was hand hoed on two different dates and all weeds were removed. The first hoeing was completed on July 6, the second on July 26. This completely eliminated the weed problem, and with the exception of some crabgrass (Digitaria sanguinalis), which grew in some of the 10-inch rows late in the season, the field was clean. The crabgrass did not start growth until late in the growing season when the sorghum was almost mature and, therefore, had very little influence on the experiment.

Even though all sorghum plants did not emerge, a sufficient stand was obtained to conduct the experiment.

On June 6 the variety Midland, dwarf grain sorghum, was planted. Seed testing 80 percent germination from the Fort Hays Experiment Station was planted with a ten-foot, twelve disk small grain drill. The disks were spaced ten inches apart on the drill.

The drill was calibrated so that the rate of seeding was approximately 18 seeds to the linear foot. A total of 34 drill widths was planted in a north-south direction. The length of the rows was 305 feet. This gave a total area of 305 x 340 feet.

Shortly after emergence the field was divided into three blocks with 20-foot roadways between the blocks and 70-foot rows within the blocks. A randomized block experiment replicated three times was used. Each block was 70 x 340 feet and contained 24 plots.

Thinning of the plots to give the proper row widths and distance between the plants within the row was completed 21 days after planting. Four different row widths, 10, 20, 30, and 40 inches and six different areas per plant, 40, 60, 80, 100, 120, and 160 square inches, were studied. Table 1 shows the design of the experiment.

Width of row was obtained by removing alternate rows in the 20-inch row widths, removing two rows and leaving one in the 30-inch row widths, and removing three rows and leaving one in the 40-inch rows. The 10-inch row widths were left as planted. The rows were removed with a wheel hoe.

Plant spacing within the row was obtained by planting thicker than the desired stand and then thinning by hand. A one x two inch board six feet long was marked to show the desired space between plants and this was used as a guide in removing the unwanted plants. If there was an insufficient number of plants in any board length it was made up in the next board length and the desired number of plants was obtained in each 70-foot row. All

thinning was completed within three weeks after planting.

The 10-inch row plots contained 12 rows, eight of which were harvested and two on each side were guard rows. The 20-inch row plots contained eight rows, six of which were harvested. The 30-inch row plots contained five rows, three of which were harvested. The 40-inch row plots contained four rows, two of which were harvested.

Table 1. Design of dwarf grain sorghum spacing experiment, 1956.

Distance between rows (inches)	Average space between plants (inches)	Average area per plant (square inches)	Approximate no. plants per acre (000)
10	4	40	157
10	6	60	105
10	8	80	78
10	10	100	63
10	12	120	52
10	16	160	39
20	2	40	157
20	3	60	105
20	4	80	78
20	5	100	63
20	6	120	52
20	8	160	39
30	1.33	40	157
30	2	60	105
30	2.67	80	78
30	3.33	100	63
30	4	120	52
30	5.33	160	39
40	1	40	157
40	1.50	60	105
40	2	80	78
40	2.50	100	63
40	3	120	52
40	4	160	39

The 40-inch rows were the only spacings to receive any post-planting cultivation. They were cultivated twice with a mounted two-row tractor cultivator. The first cultivation was 15 days after emergence, the second, 38 days after emergence.

Harvesting was accomplished on September 4 by cutting the heads by hand with linoleum knife and allowing them to dry on wire trays in the field for two weeks. A portable, gasoline engine powered "Vogel" thresher was used to thresh the grain in the field. The grain was then sacked by plots, tagged and taken to the agronomy farm barn for further processing.

Shortly after date of planting it became apparent, by examining the surrounding areas, that chinch bugs (Blissus leucopterus) were going to present a serious threat to the sorghum unless some means of control was employed. In order to limit the damage to the plots themselves, a strip 30 feet wide around the outside borders of the field was sprayed every five days, starting at the time the sorghum emerged and continuing until it had reached a stage of growth where the chinch bugs would no longer do any serious damage. The plots were also sprayed on two dates, June 15 and July 2. Commercial "dieldrin" was used as the insecticide. Some bugs still managed to enter the plots but not in sufficient numbers to do any apparent damage.

The date recorded as first head was the day on which about 10 percent of the heads were completely out of the boot. Date of full head was recorded when the heads were in about one-third bloom.

Due to environmental conditions there was no tillering of

any significance in any of the plots.

Records of the temperature, rainfall, and wind movement at the Agronomy farm are recorded in Table 2.

Although precipitation for the period was nearly normal, much of it was received in light showers and was lost by evaporation within a short time.

The evaporative power of the atmosphere in the plots was measured by use of Livingston porus, clay-cup atmometer bulbs. These atmometers were mounted on quart glass bottles as described by Weaver and Clements (32) and Loomis and Shull (11). The atmometers were assembled and tested for five days in the laboratory before placing them in the field.

The atmometers were placed in the center of the rows with the bulbs approximately 12 inches above the ground. As a precaution against the instruments tipping over, they were placed in quart oil cans which had both ends removed. The cans were first forced into the soil until they were quite steady before placing the instrument in the can. Atmometers were maintained in the field for 28 days.

Two atmometers were placed in each of the four different row widths. The plant population was the same in all cases, being 80 square inches per plant. The location within a plot was changed at the end of each seven day period.

Also, two atmometers were placed in each of four different plant areas, 40, 80, 120, and 160 square inches, in both 40- and 20-inch rows. The location within a plot was changed after each seven day period.

Table 2. Daily maximum and minimum temperatures, precipitation, and wind movement (miles per day) for Manhattan, Kansas, June 1, 1956, to August 31, 1956.

Date	June Max.	June Min.	June Prec.	June Wind	July Max.	July Min.	July Prec.	July Wind	August Max.	August Min.	August Prec.	August Wind
1	71	42		28	109	77		96	102	69	.03	43
2	71	49		37	99	70		91	98	69	.77	62
3	79	56	.13	93	88	65	1.94	90	96	73		--
4	83	61		66	88	67	.45	24	101	78		70
5	81	65	.26	87	85	66		33	104	72		44
6	83	65	.21	137	89	66		47	102	72		56
7	82	61	.58	28	92	73		88	96	68		96
8	87	56		135	96	64		63	94	69	.08	112
9	81	56		35	85	57		32	97	65	1.65	78
10	88	61		20	81	55		36	87	65	.68	60
11	89	61		57	92	64		47	79	65	.31	20
12	89	68		67	94	64	.94	115	82	66	.09	35
13	95	68		81	87	68	.73	47	99	69		25
14	92	66		95	90	72		22	89	63		48
15	87	62		66	96	73	.12	56	94	70		47
16	86	67		79	100	70	.12	43	99	76		28
17	87	64	1.45	114	90	63		44	105	76		25
18	87	65		86	85	66		18	98	72		36
19	95	70		66	90	66		24	85	57		81
20	98	73		52	84	58		19	71	50		69
21	99	74		87	84	58	.22	24	76	45		24
22	102	71		73	85	62		45	83	50		32
23	83	63	.43	50	85	64	.31	50	98	60		24
24	94	67	.65	53	83	65		36	98	68		47
25	93	69		33	98	63		24	86	62		50
26	92	65	.03	88	93	71		33	99	64		89
27	89	64		25	105	78		49	100	74		52
28	93	62	.10	44	105	77		43	98	71		144
29	87	63		45	104	71	.24	30	99	72		108
30	96	65		115	91	69		45	91	72		48
31					101	74		66	96	68		52

The readings were taken at the same hour each day, weather conditions permitting. The atmometers were filled daily with distilled water from a 100 m.l. graduated cylinder and the quantity of water needed to fill the bottles back to the zero mark was recorded. The amount of water lost from each atmometer was then multiplied by the correction factor for that particular bulb and the corrected water loss recorded.

A tooth brush and distilled water were used to clean the bulbs at each days filling.

Soil temperature readings were taken with centigrade mercury thermometers. Two different row widths were used, 20-inch and 40-inch, both with the same area per plant, 80 square inches. Temperature readings were taken from July 18 to August 8.

Soil temperature readings were taken hourly at a depth of two inches and at distances of 4, 12, 20, 28, and 36 inches from the east row in a pair of 40-inch rows. Corresponding readings were taken in a pair of 20-inch rows at distances of 3, 10, and 17 inches from the east row.

Soil temperature readings were taken hourly at the surface and at depths of 2, 4, and 6 inches. These thermometers were located in the center of two rows in both the 20- and 40-inch rows.

Daily maximum and minimum surface soil temperatures were recorded midway between 40-inch rows from July 20 until July 30. Similarly, these readings were taken midway between 20-inch rows from July 31 until August 8. A set of maximum-minimum surface soil thermometers was used.

Maximum and minimum air temperatures were taken in the 40- and 20-inch rows at a height of 12 inches above the ground (atmometer bulb height) from July 19 to July 23 and from July 31 to August 8. The thermometers were changed to a position just under the upper leaves from July 24 to July 30. The thermometers were shielded from the sun but had free air movement around them. A set of maximum-minimum air thermometers was used.

Plant heights were taken on August 15, 10 days after full heading. The average height was obtained by taking two measurements from each of the replicated plots. Each measurement was made by sighting along the top of the row to a measuring stick in the middle of the plot and recording the height.

Notes on the percent of ground area shaded between rows were taken on July 25 and August 14. These readings were taken by estimating the amount of shaded area between the rows in each of the plots and then averaging the three plots.

Notes on the rate of drying of the surface soil were taken following the rainfall of August 8 to 12 (2.81 inches). These readings were made by observing the color of the surface soil and estimating the amount of drying in each of the plots.

The acre yields per plot were calculated by the following formulae:

For 40-inch and 10-inch rows:

$$\frac{43560}{70 \times 6.67 \times 56} = 1.66684 \times \text{wt. grain per plot equals bushels per acre}$$

For 30-inch rows:

$$\frac{43560}{70 \times 7.5 \times 56} = 1.48163 \times \text{wt. grain per plot equals bushels per acre}$$

For 20-inch rows:

$$\frac{43560}{70 \times 10 \times 56} = 1.11122 \times \text{wt. grain per plot equals bushels per acre}$$

The test weight per bushel was determined by use of the method and Fairbanks scale described in the U. S. D. A. bulletin No. 1065, May 18, 1922. Three weights were taken from each plot and an average computed.

The size of kernel was recorded as the weight of 1,000 kernels in grams. This weight was computed by using a screen to remove the dockage and then counting out three samples of 500 kernels each. The average weight of 1,000 kernels was then computed from the weight of these three samples.

Size of head was determined by dividing the total weight of grain per plot by the number of heads harvested. It was recorded in pounds per 100 heads.

The methods of statistical analysis used were those described by Snedecor (26) and by the Statistics Department at Kansas State College.

EXPERIMENTAL RESULTS

In order to show the effects of the different row widths and spacings on the growth and development of the sorghum crop more clearly, the experimental results reported in this thesis are divided into sections. The sub-divisions are: (a) shading, (b) evaporative power of the air, (c) soil and air temperature within rows, (d) rate of drying of surface soil, (e) height of plants, (f) yield of grain, (g) test weights, (h) number of heads, and (i) size of heads.

Shading

It has been suggested that shading at the soil surface is effective in reducing water loss by lowering the evaporation rate from the soil and decreasing the amount of transpiration from the plants. It was also suggested by Wilkins (33) and Stickler (27) that this shading and reduction of light intensity is effective in controlling weeds in the narrower row spacings. These factors are probably important in the successful production of dwarf grain sorghum in the narrower row spacings without any post-planting cultivation.

Table 3 is presented to show the amount of shading as it was influenced by the different row widths at three different times during the day. By 40 days after planting, July 15, the only spacings that had reached their maximum shading were the lower areas per plant in the 20-inch rows. Because of the direction of the rows and the altitude of the sun somewhat less shading was provided at 1:30 P. M. than at either 10:30 A. M. or 3:30 P. M.

By August 14, when the plants had reached maximum vegetative development, the 20-inch rows still appeared to provide the greatest amount of shade but were little better than the 10-inch rows. As the row width increased to greater than 20 inches, less shading was provided. The 40-inch rows afforded considerable less shade than the 30-inch rows.

Maximum shading in both 20- and 40-inch row widths was provided by the 40-square-inch per plant spacings. In all row widths the shaded area tended to decrease rather sharply as the area per plant was increased.

Table 3. Percent of ground surface shaded by dwarf grain sorghum.

Row width (inches)	Area per plant (sq. in.)							
	40	80	120	160	40	80	120	160
	July 25				August 14			
	10:30 A. M.							
10		80		45		90		55
20	100	90	75	50	100	90	80	65
30		65		45		80		45
40	50	45	35	35	55	50	40	40
	1:30 P. M.							
10		60		30		80		60
20	90	80	65	50	95	90	75	55
30		60		35		65		45
40	45	40	25	30	55	50	40	35
	3:30 P. M.							
10		90		75		95		70
20	100	95	90	80	100	95	85	80
30		90		80		90		80
40	85	75	70	75	90	85	75	75

If weed control had been dependent on the effects of shading and light intensity, it appears that the 10- and 20-inch rows would have been the most effective. The 30-inch rows would have been somewhat less effective and the 40-inch rows even less effective.

Due to a reduction in the amount of sunlight striking the soil in the 10-, 20-, and 30-inch rows as compared to the 40-inch rows, and consequently less heat in the narrower spacings, it is suggested that this might have resulted in less moisture loss from the narrow spacings.

Evaporative Power of the Air

This study was made in three different situations, different row widths with the same area per plant, and 20- and 40-inch rows

with different areas per plant. The Livingston atmometer bulbs which were used to measure the evaporation give only an indication of the relative amount of evaporation, and not a direct measure of it.

A comparison of the evaporative power of the air was made between all row widths with 80 square inches per plant. Table 4 records these data.

Table 4. Effect of row width on evaporation within dwarf grain sorghum rows (plant space equals 80 square inches).

Row width (inches)	Water loss from atmometer bulbs (c.c.)* July 18-24	July 25-31	Aug. 1-7	Aug. 8-14	Total
10	101	239	230	97	667
20	96	220	214	93	623
30	112	226	231	103	672
40	131	295	277	98	801
Average temperatures:					
Maximum	85	100	100	90	
Minimum	63	72	72	66	
Wind movement (av. mi. day)	30	41	53	54	
Precipitation	.53	.24	.80	2.81	

*Each figure represents the average loss at two locations.

It appears that there was little difference in the quantity of water evaporated among the 10-, 20-, and 30-inch rows. When the row width was increased to 40 inches the amount of water evaporated was considerably greater. The total corrected water-loss was 1.29 times as much in the 40-inch rows as in the 20-inch rows, and 1.19 and 1.20 times as much as in the 30- and 10-inch rows respectively.

This could possibly mean that in the narrower row spacings the humidity is increased, due to lower temperatures and less

evaporation as a result of shading. This could lead to less transpiration by the plants.

The high water losses during the two seven-day periods from July 25 to August 7 were probably a result of the high temperatures during this time.

Table 5. Effect of distance between plants on evaporative power of the air in 40- and 20-inch rows.

Row width (in.)	Water loss from atmometer bulbs (c.c.) July 18 to Aug. 14*				
	Area per plant (sq. in.)				
	40	80	120	160	Average
40	792	801	899	906	850
20	577	623	619	724	636

*Each figure represents the average loss at two locations.

Table 5 records the evaporation data when four different plant spacings are compared in 40- and 20-inch rows. When the four different plant spacings are considered, there was 1.34 times as much evaporation from the 40-inch rows as from the 20-inch. In each spacing the evaporation was considerably greater in the 40-inch rows. The daily average evaporation for the 28-day period was 30.4 c.c. for the 40-inch rows and 22.7 c.c. for the 20-inch rows. In either row width the closer plant spacings were more effective in reducing evaporation than the wider spacings.

These results closely agreed with the findings of Wilkins (33) and Stickler (27).

Soil and Air Temperature within the Rows

A study was made to determine the effect of row width on the temperature of the surface soil at different locations between the rows and also at depths of 2, 4, and 6 inches in the center of the rows. Temperatures were recorded hourly during the day beginning at 9:00 A. M. from July 18 to August 8.

Soil temperatures at a depth of two inches were recorded in 40- and 20-inch rows, both with 80 square inches per plant, at different distances between the rows. These data are presented in Tables 6 and 7.

Table 6. Average hourly trends of soil temperature two inches deep between 40-inch rows (degrees F.).

Time of day	Distance of thermometer from east row (inches) 4	12	20	28	36
9:00	75.8	75.3	75.7	75.7	75.9
10:00	77.6	77.4	77.9	78.6	82.1
11:00	79.5	79.5	81.5	87.2	89.3
12:00	80.6	81.5	86.9	93.0	91.9
1:00	83.0	89.6	96.3	94.4	88.2
2:00	85.0	94.5	96.4	91.8	87.3
3:00	90.0	94.3	91.5	88.7	85.8
4:00	89.5	90.1	89.3	87.6	85.4
5:00	87.4	88.2	87.7	86.7	85.0

In the 40-inch rows the maximum temperature was reached at a distance of 20 inches from the east row, or in the center of the rows. The maximum temperatures reached decreased at about the same rate as the location approached nearer to either row. The lowest maximum temperatures occurred at distances of four inches from the rows, where shade was provided by the plants for a longer period

Table 7. Average hourly trends of soil temperature two inches deep between 20-inch rows (degrees F.).

Time of day	Distance of thermometer from east row (inches) 3	10	17
9:00	75.1	75.6	75.3
10:00	77.6	78.4	77.3
11:00	80.1	80.7	79.4
12:00	81.3	81.6	80.8
1:00	83.2	83.5	82.2
2:00	84.2	84.1	82.9
3:00	84.3	84.3	82.8
4:00	83.8	83.8	82.7
5:00	83.4	83.6	82.6

during the day. The time of day at which the maximum temperature was reached differed with the distance from either row. When the location was nearest the west row the temperature reached its maximum at the earliest hour. At a distance of four inches from the west row the highest temperature was reached at 12:00, while the maximum was not reached until 3:00 P. M. at a distance of four inches from the east row.

In the 20-inch rows the temperature remained almost uniform across the entire width at any particular time. The rise in temperature was uniform across the rows and the maximum temperatures reached were considerably lower than in the 40-inch rows.

These data suggest that the 20-inch rows were more effective in shading and in preventing solar energy from reaching the soil than were the 40-inch rows. The 20-inch rows gave effective shading, even in the center of the rows, while the 40-inch rows did not.

Data from the study of soil temperatures at different depths are recorded in Tables 8 and 9.

Table 8. Average hourly trends of soil temperature at different depths in 40- and 20-inch rows (degrees F.).

Time of day	40-inch rows: Surface	2	4	6	20-inch rows: Surface	2	4	6
	Depth in inches							
9:00	79.5	75.7	75.5	75.5	78.5	75.6	74.1	74.0
10:00	83.3	77.9	75.8	75.5	81.8	78.4	75.5	74.5
11:00	95.2	81.5	77.5	76.3	84.9	80.7	77.1	75.7
12:00	106.9	86.9	79.4	77.3	86.9	81.6	78.3	76.4
1:00	108.1	96.3	84.5	80.2	92.5	83.5	80.0	77.8
2:00	105.2	96.4	86.2	81.5	90.2	84.1	81.1	78.8
3:00	96.7	91.5	86.8	82.9	89.4	84.3	81.4	79.1
4:00	92.7	89.3	86.1	83.2	87.7	83.8	81.5	79.4
5:00	91.9	87.7	86.0	83.2	86.6	83.6	81.2	79.4

Table 9. Soil temperatures at 1:00 P. M. on July 23 and July 25 at different depths between 40- and 20-inch rows.

Date	40-inch rows: Surface	2	4	6	20-inch rows: Surface	2	4	6
	Depth in inches							
July 23	107	93	82	77	90	81	77	75
July 25	131	102	86	79	107	83	80	78

At any soil depth the maximum temperature reached in the 40-inch rows was higher than in the 20-inch rows. The difference was greatest at the surface and decreased at the lower depths. The surface soil heated and cooled very rapidly in both of the row widths. Due to the insulating properties of the soil, the temperature increased at a slower rate at the greater depths and did not reach as high a maximum temperature. The maximum temperatures at the same depths in the different row widths occurred at about the same times.

This study indicates that the 20-inch rows were not only more effective in maintaining a lower surface soil temperature but also in reducing the temperatures below the surface, to a depth of at least six inches.

Table 9 records the soil temperatures at 1:00 P. M. on two different dates. On July 23 the maximum temperature was only 85 degrees with a cool breeze and few clouds. July 25 was much warmer with a maximum temperature of 100 degrees and a clear sky.

The surface soil temperatures in both row widths exceeded the maximum temperature for the day on both dates. In the 40-inch rows the soil temperature at a depth of two inches also exceeded the maximum air temperature for the day, while in the 20-inch rows it did not.

From the above data it is evident that there was considerable difference in temperatures between the two row widths on cool days as well as on warmer days.

In the study in which maximum and minimum surface soil thermometers were maintained in the 40- and 20-inch rows, the highest recorded temperature in the 40-inch row was 143° F., and 107° F. in the 20-inch rows. The minimum night time temperatures of the surface soil in the two row widths was the same. This further indicates the shading effect and the lower evaporation stress of the 20-inch rows as compared to the 40-inch.

In order to determine the effect of the row widths on the air temperature within the rows, maximum and minimum air temperature thermometers were placed in 40- and 20-inch rows. These temperatures are recorded in Table 10.

Table 10. Maximum-minimum air temperatures in 40- and 20-inch rows with 80 square inches per plant, (degrees F.).

Date	40-inch rows		20-inch rows	
	Maximum	Minimum	Maximum	Minimum
	Temperature 12 inches above ground			
July 19	94	54	92	55
20	96	56	91	57
21	92	61	89	61
22	97	62	93	62
23	93	62	91	62
	Temperature just below upper leaves			
24	101	59	98	59
25	103	64	101	64
26	108	73	108	73
27	107	69	107	69
28	109	69	108	69
29	98	68	99	68
30	100	72	102	72
	Temperature 12 inches above ground			
31	110	68	104	68
Aug. 1	104	69	102	69
2	95	68	94	68
3	101	71	100	71
4-5	114	66	106	66
6	104	64	99	64
7	104	68	98	68

At a position of 12 inches above the ground the daily maximum temperatures in the 40-inch rows averaged 3.75 degrees higher than in the 20-inch rows. On no date was the maximum temperature reached in the 20-inch rows as high as in the 40-inch rows.

At a position of just below the upper leaves the maximum temperatures in the 20-inch rows were similar to those in the 40-inch rows. This is probably a result of less shading effect at the higher positions.

The minimum air temperatures between the different row widths were the same at both heights.

It is suggested that the higher temperatures, both of the soil and of the air, are in part responsible for the higher amount of evaporation in the 40-inch rows.

Rate of Drying of Surface Soil

Notes on the rate of drying of the surface soil were taken by visual observation following the 2.81 inches of rainfall of August 8 to 12. On August 13 the surface soil was thoroughly wet between all rows, the day was cloudy, and the maximum temperature was 99 degrees. By the afternoon of August 14 very little drying had occurred in the 10- and 20-inch rows while in the 30- and 40-inch rows about 25 percent of the surface soil area had dried. The day was clear with a moderate southerly breeze. The maximum temperature was 89 degrees.

On August 15 there was very little air movement during the day, no clouds and the maximum temperature was 94 degrees. By the afternoon of August 15 more than 50 percent of the surface soil appeared dry in the 30- and 40-inch rows while the 10- and 20-inch rows had just begun to show some evidence of drying.

By the afternoon of August 16 the 10-, 30-, and 40-inch rows all appeared to be about 90 percent dry while only about 50 percent of the surface soil appeared dry in the 20-inch rows.

Although the different row widths appeared to have different rates of drying of the surface soil, by the afternoon of August 17, five days after the period of precipitation, the surface soil in all row widths appeared dry.

These different rates of drying in the different row widths seemed to correspond to both the amount of shading provided by the

plants and the temperatures within the rows. The narrow row widths provided more shaded area between the rows and lower temperatures which tended to decrease the rate of drying of the surface soil following a period of rainfall.

Height of Plants

The heights of plants as measured on August 15 are recorded in Table 11.

Table 11. Height of plants in inches on August 15.

Row width (in.)	Plant space (square inches)						
	40	60	80	100	120	160	Average
10	37.0	35.0	34.5	35.0	35.5	36.0	35.5
20	41.5	40.0	39.5	38.5	37.5	36.0	38.8
30	42.0	43.0	41.0	41.0	37.5	36.0	40.1
40	37.0	39.5	40.0	39.5	37.5	37.5	38.5
Average	39.4	39.4	38.8	38.5	37.0	36.4	

* l.s.d. for average heights of rows = 1.93 inches.
l.s.d. for average heights of areas = 2.36 inches.

An increase in height was associated with a decrease in plant area. Plants growing in the 40- and 60-square-inch areas were significantly taller than those growing in the 120- and 160-square-inch areas.

The different areas appeared to have little affect on plant height in the 10- and 40-inch rows, but had a marked influence in the 20- and 30-inch rows.

* l.s.d.'s and tests of significance in this paper are computed at the .05 level of probability.

Row width also affected the height of plants. There was no significant difference between the 20-, 30-, and 40-inch rows but these three row widths were all significantly taller than the 10-inch rows.

The 10-inch rows were most uniform in height, regardless of the different areas per plant. The two larger plant areas, especially the 160-square-inch spacing, were most uniform in height, regardless of row width.

Competition for light was probably the greatest factor in influencing plant height. The shape of the area, as well as the size of the area in which the plant was growing, also appeared to influence the height. Both the shape and size of the area were important in determining the amount of light falling on the plants.

Yield of Grain

In the practice of growing grain sorghums the primary objective is to obtain the maximum acre yield of grain. Table 12 presents the acre yields by row widths and plant spacings.

Table 12. Effect of row width and plant space on acre yield of grain.

Row width (in.)	Yield (bu./acre)						
	Area per plant (sq. in.)						
	40	60	80	100	120	160	Average
10	18.0	26.4	28.1	32.2	31.7	34.9	28.5
20	36.0	45.1	46.9	46.0	46.4	42.2	43.8
30	45.4	51.9	53.3	51.8	34.5	33.3	45.0
40	18.7	31.4	34.5	32.3	30.7	33.5	30.2
Average	29.5	38.7	40.7	40.6	35.8	36.0	

l.s.d. for average yields of rows = 7.8 bushels.
l.s.d. for average yields of areas = 9.6 bushels.

The row width had a marked influence on the acre yield. The 20- and 30-inch rows had a significantly higher yield than the 10- and 40-inch rows. There was little difference between the yields of the 20- and 30-inch rows and also between the 10- and 40-inch rows. Yields in the 20-inch rows were higher in all plant spacings than those of the 10- and 40-inch rows. The 30-inch rows had the highest yields in all except the 120- and 160-square-inch spacings.

Average yield was significantly higher in the 80- and 100-square-inch spacings than in the 40-square-inch spacing. The 40-square-inch spacings gave the lowest yields in all except the 30-inch rows. The 80-square-inch spacings gave the highest yields in all except the 10-inch rows.

When all row widths are considered, the 80- and 100-square-inch spacings appeared to be superior to other spacings in production of higher yields. In this study it appeared that sorghum growing in spacings of greater than 100-square-inches per plant was not able to fully utilize the space.

A comparison of the yields of 40- and 20-inch rows of Midland grain sorghum grown at Manhattan for a 13-year period is shown in Table 13. The average advantage of the 20-inch rows was 11.8 bushels over the wider row width, or a 26 percent increase in yield.

From the data presented in this study it is indicated that both row width and plant spacing, independently and in combination, affect the acre yield of dwarf grain sorghum. When either the row width or plant spacing is increased or decreased beyond optimum limits the yield is decreased.

Table 13. Acre yield (bu.) of Midland grain sorghum at Manhattan, Kansas, for 13 years.

Year	Row width (in.) 40	20	Advantage for narrow rows
1944	43.8	59.0	15.2
1945	32.6	65.1	32.5
1946	27.7	27.2	- .5
1947	20.5	26.0	5.5
1948	52.4	68.3	15.9
1949	73.0	86.2	13.2
1950	80.5	92.0	11.5
1951	64.3	80.6	16.3
1952	17.3	28.6	11.3
1953	85.0	88.3	3.3
1954	45.1	61.8	16.7
1955	26.4	26.0	- .4
1956	30.2	43.8	13.6
Average	46.1	57.9	11.8

Number of Heads

Table 14 is presented to show the influence of row width and plant spacing on the average number of heads produced by plants in the different arrangements.

Table 14. Effect of plant space and row width on average number of heads produced (average number of heads per 100 plants).

Row width (in.)	Area per plant (sq. in.) 40	60	80	100	120	160	Average
10	55	76	80	91	115	113	88
20	68	77	88	98	97	106	89
30	68	78	84	91	94	104	87
40	54	68	87	90	84	101	81
Average	61	75	85	93	98	106	

The area per plant exerted more influence on the number of heads produced than did row width. In each of the row widths the number of heads produced by a given number of plants tended to increase as the plant area increased.

There was little difference in the number of heads produced in the different row widths, the range being from 81 heads per 100 plants in the 40-inch rows to 89 heads per 100 plants in the 20-inch rows.

The greatest average number of heads per plant occurred in the 120- and 160-square-inch area in the 10-inch rows, a probable explanation for this being that more light at the base of the plant tended to stimulate more tillering and these tillers were able to produce heads.

It appears that the size of the area in which the plant was grown was more important than the shape of the area.

Size of Heads

The size of head is influenced mainly by two factors, number of kernels per head and size of kernel. The yield in turn is influenced by the size of head and number of heads per given area.

A study was made to determine the affect of the different row widths and spacings on the size of head. These data are presented in Table 15.

The 20- and 30-inch rows produced significantly larger heads than the 10- and 40-inch rows. This significant difference in head size was reflected directly in the acre yield of the different row widths.

Table 15. Effect of row width and plant space on size of head (pounds of grain per 100 heads).

Row width (in.)	Area per plant (sq. in.) 40	60	80	100	120	160	Average
10	1.123	1.830	2.463	2.947	2.947	4.527	2.640
20	1.927	3.051	3.710	4.285	5.125	5.660	3.960
30	2.510	3.494	4.546	4.917	3.954	4.533	3.993
40	1.309	2.654	2.828	3.198	3.858	4.812	3.110
Average	1.717	2.757	3.387	3.837	3.971	4.883	

l.s.d. for average of rows = .698 pounds.
l.s.d. for average of areas = .856 pounds.

Although the row widths had an effect on the size of head, the greatest influence seemed to be by the different plant spacings. The 160-square-inch spacing produced significantly larger heads than any other spacing. However, this increase in head size was not sufficient to compensate for the decreased number of heads per acre and a lower yield resulted.

The 40-square-inch spacing produced significantly smaller heads than any other spacing. The head size in the 40-square-inch spacing was reduced to such an extent that even with the increased number of heads per acre a lower acre yield resulted.

The 100- and 120-square-inch spacings also gave significantly larger heads than the 60-square-inch area.

Apparently in the 80- and 100-square-inch areas the optimum size of head combined with the optimum number of heads per given area to give the higher yields.

In all row widths the size of head increased as the space per plant increased, with the exception of the two widest spacings in the 30-inch rows.

Studies were made to determine the influence of row width and plant area on the size of kernel and number of kernels per head, as these are both factors which influence the size of head. Data from these studies are presented in Tables 16 and 17.

Both the row width and area per plant influenced the number of kernels per head, with the different spacings having the greatest effect.

Both the 30- and 20-inch rows produced a significantly larger number of kernels per head than the 10- and 40-inch rows.

Table 16. Effect of row width and plant space on number of kernels per head.

Row width (in.)	Area per plant (sq. in.) 40	60	80	100	120	160	Average
10	206	320	437	518	546	806	472
20	343	535	648	734	886	1032	696
30	443	606	808	873	706	812	708
40	258	476	499	566	684	850	556
Average	313	484	598	673	706	875	

l.s.d. for average of rows = 119 kernels.
l.s.d. for average of areas = 146 kernels.

This is the same relationship that existed between the different row widths when yield was considered. This shows that the higher yielding row widths produced heads with a greater number of kernels when all plant spacings are considered.

The different plant areas had even more influence on the number of kernels per head. There was a consistent increase in the number of kernels per head as the area per plant increased. The 40-square-inch area produced a significantly smaller number and

the 160-square-inch area produced a significantly larger number of kernels per head than all other areas. This was also true in all row widths except the 120- and 160-square-inch areas in the 30-inch rows.

Table 17. Effect of row width and plant space on size of kernel, (average weight of 1000 kernels in grams).

Row width (in.)	Area per plant (sq. in.)						
	40	60	80	100	120	160	Average
10	24.48	25.75	25.29	25.27	23.61	25.28	24.95
20	25.34	25.77	25.83	26.16	26.24	24.92	25.71
30	25.70	26.11	25.54	25.52	25.41	25.36	25.61
40	22.76	25.09	25.43	25.71	25.59	25.72	25.05
Average	24.57	25.68	25.53	25.66	25.21	25.32	

l.s.d. for average of rows = .63 grams.
l.s.d. for average of areas = .77 grams.

The 120- and 100-square-inch areas produced a significantly greater number of kernels per head than the 60-square-inch area.

Both row width and size of area, separately and in combination affected the number of kernels per head. The significant differences compare exactly with those for size of head, showing that the size of head was influenced to a large extent by the number of kernels per head.

When the size of kernels are compared among the different areas and row widths the influence is less apparent. The kernel size in the 30- and 20-inch rows was significantly larger than in the 10-inch rows. The 20-inch rows also produced significantly larger kernels than the 40-inch rows.

The different spacings appeared to have less influence on the kernel size than on some of the other factors. The only significant difference appeared between the 40-square-inch spacing and the 60-, 80-, and 100-square-inch spacings. There did not appear to be any definite trend between area per plant and size of kernel.

The above data show that the size of head, expressed in weight of grain per 100 heads, was influenced by the number of kernels per head and by the size of kernel, expressed in weight per 1000 kernels, but that the number of kernels per head was the more important factor. Row width and area per plant affected both of these factors but had less effect on size of kernel than on number of kernels per head.

Test Weights

The weight per bushel of sorghum in the 1956 spacing experiment was above the standard 56 pounds per bushel in all plots.

Table 18. Effect of row width and plant space on test weight of grain (lbs./bu.).

Row width (in.)	Area per plant (sq. in.)						
	40	60	80	100	120	160	Average
10	58.6	59.5	58.7	59.5	56.9	59.1	58.7
20	60.5	60.9	60.8	60.1	60.6	60.2	60.5
30	61.3	61.7	61.0	61.8	60.4	60.2	61.1
40	58.0	60.4	60.7	60.5	59.9	59.7	59.9
Average	59.6	60.7	60.3	60.5	59.4	59.8	

l.s.d. for average of rows = .8 pounds.
l.s.d. for average of areas = 1.0 pounds.

From this study it was found that area per plant had less influence on test weights than did row width. The 30-inch row widths had significantly higher test weights than 10- and 40-inch rows and the 20-inch rows were significantly higher than the 10-inch rows.

Although test weights were significantly higher in the 60- and 100-square-inch spacings than in the 120-square-inch spacing and significantly higher in the 60- than in the 40-square-inch spacing, there appeared to be no general trend between test weights and plant spacing when all areas were considered.

Summary Tables

Summaries of the effects of row width and plant spacing on dwarf grain sorghum in this study are presented in Tables 19 and 20.

Table 19. Summary table of effects of row width on dwarf grain sorghum, Manhattan, Kansas, 1956.

Row width (inches)	Yield bu./ acre	Size of head lbs./ 100 heads	Kernels per head	Size of kernel gm./1000	Test weight lbs./bu.
10	28.5	2.640	472	24.95	58.7
20	43.8	3.960	696	25.71	60.5
30	45.0	3.993	708	25.61	61.1
40	30.2	3.110	556	25.05	59.9

The optimum row width and plant spacing were obtained in the 20- and 30-inch rows and between 60- and 100 square inches per plant. These two factors combined to give maximum yield of grain.

Table 20. Summary table of effects of plant spacing on dwarf grain sorghum, Manhattan, Kansas, 1956.

Area per plant (sq. in.)	Yield bu./ acre	Size of head lbs/ 100 heads	Kernels per head	Size of kernel gm./1000	Test weight lbs./bu.
40	29.5	1.717	313	24.57	59.6
60	38.7	2.757	484	25.68	60.7
80	40.7	3.387	598	25.53	60.3
100	40.6	3.837	673	25.66	60.5
120	35.8	3.971	706	25.21	59.4
160	36.0	4.883	875	25.32	59.8

The yield was influenced by the size of head and the number of plants per acre. The size of head was determined by the number of kernels per head primarily, but was also influenced to some extent by size of kernel.

Maximum test weights were obtained under the same plant arrangements that produced the highest yields.

SUMMARY

The dwarf grain sorghum spacing experiment for 1956 was conducted on the Kansas Agricultural Experiment Station agronomy farm at Manhattan.

Midland grain sorghum was planted on June 6. The experiment was conducted in a randomized block design replicated three times. Each block was 70 by 340 feet with the rows running across the block.

After emergence plants were thinned to give six different plant spacings in each of four different row widths.

Previous experimental work at Manhattan has shown that when dwarf grain sorghum was grown in 20-inch rows as compared to 40-inch rows, the 20-inch rows resulted in higher acre yields.

This thesis presents the results of one year's study, 1956, of the influence of row width and plant spacing on some of the agronomic factors affecting plant growth and acre yield. Factors studied were shading, evaporative power of the air, soil temperature, and air temperature.

CONCLUSIONS

Conclusions from this experiment which are supported by the material presented in this paper are given below.

The 10- and 20-inch rows were more effective in shading the surface soil between rows than the 30- and 40-inch rows.

The 40-square-inch spacing gave more effective shading in all row widths than the wider spacings.

Evaporation was greater in the 40-inch rows than in any other row width. In the 80-square-inch area the evaporation from the 40-inch rows was 1.29 times greater than from the 20-inch rows, and 1.19 and 1.20 times as much as from the 30- and 10-inch rows respectively.

When four plant spacings, 40, 80, 120, and 160 square inches were tested, the evaporation from 40-inch rows was 1.34 times as much as from 20-inch rows. The evaporation from 40-inch rows exceeded that from 20-inch rows in all cases.

The 20-inch rows gave effective shading between the rows and the soil temperature at a depth of two inches remained uniform

across the rows throughout the day. The 40-inch rows did not effectively shade the area between the rows and the soil temperature increased toward the center of the rows and also reached a higher maximum temperature than in the 20-inch rows. This indicated that more solar energy was intercepted by the plants in the narrower row spacings.

The difference in soil temperature was evident from the surface soil to a depth of at least six inches. The same trends were followed at the greater depths, but the temperature difference became less between the 40- and 20-inch rows as the depth increased. There was also a time lag at the lower depths.

Air temperatures were lower in the narrower row spacings, except at a position of just below the upper leaves, where shading was reduced and there were no noticeable temperature differences. There was no difference in the minimum temperatures reached in the wide and narrow row widths.

The narrower row spacings resulted in a slower rate of drying of the surface soil following a period of precipitation. Less air movement, lower temperatures and less evaporation as a result of more effective shading of the soil in the narrower rows appeared to be important factors.

Height of plants was influenced by both area and row width separately and in combination. The narrowest row width and the greatest area per plant produced the shortest plants. Competition for light was probably the factor resulting in the difference in heights.

Yield of grain was influenced by both row width and plant spacing. The optimum conditions for maximum acre yield were obtained in the 20- and 30-inch rows with an area of 80 or 100 square inches per plant.

Size of head increased as area per plant increased, with the largest heads being produced in the 160-square-inch area. Row width had less effect on head size than did area per plant. Although the heads produced in the 80- and 100-square-inch areas were not the largest, the size of head and number of heads per given area resulted in the highest yields.

Size of head was determined more by the number of kernels per head than by the size of kernel. The different plant areas had the greatest influence on the number of kernels per head with the larger areas producing the greatest number of kernels. The 30- and 20-inch rows produced a significantly greater number of kernels per head than the other row widths.

Both row width and plant area had less effect on the size of kernel. Although the 30- and 20-inch rows tended to produce the largest kernels, there was no definite relationship between area per plant and kernel size.

Test weights were well above the 56 pounds per bushel standard. Row width appeared to exert more influence on test weights than area per plant. The highest test weights were obtained in the 30-inch rows, which were followed by the 20-inch rows. The 60- to 100-square-inch areas produced the highest test weights, with a lower test weight resulting when the area was either increased or decreased.

Differences in row width and plant spacing (area per plant) influenced shading, evaporation, soil and air temperatures, drying of surface soil, height of plants, yield of grain, size of heads, and test weights.

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A STUDY OF THE EFFECTS OF ROW WIDTH AND
PLANT SPACING IN DWARF GRAIN SORGHUMS

by

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Sorghum has become an increasingly important crop in the United States since its introduction in 1853.

The sorghum crop is important in the Great Plains region for several reasons. It is better adapted to the severe climate than corn, it can be grown on a wide variety of soils found in the region, it is relatively free of serious diseases and insect pests, and can serve as an excellent catch crop on land where winter wheat is abandoned.

Previous studies have shown that dwarf grain sorghums gave higher yields when grown in row widths narrower than the usual 40 or 42 inches. The purpose of this study was to investigate some of the factors important in the production of higher yields from the narrower rows.

Midland dwarf grain sorghum was planted on June 6, 1956, at the Agronomy farm. A randomized block design with three replications was used. Each block was 70 by 340 feet and contained 24 plots. Four row widths, 10, 20, 30, and 40 inches, and six plant spacings, 40, 60, 80, 100, 120, and 160 square inches were studied. The desired spacings were obtained by hand thinning.

Data were taken on height of plants, yield of grain, size of heads and test weight of grain. Estimates were made on the amount of surface soil shaded between the rows and on the rate of drying of the surface soil following a period of precipitation.

Evaporative power of the air between the rows was measured by Livingston porus clay-cup atmometers.

Soil and air temperatures between the rows were measured by centigrade mercury thermometers.

Plants in the 10- and 20-inch rows proved to be more effective in shading the surface soil between rows than plants in the 30- and 40-inch rows. The wider plant spacings gave less effective shading than the closer spacings in any row width.

Evaporation was greater in the 40-inch rows than in any other row width. When four different plant spacings were tested, 40, 80, 120, and 160 square inches, the evaporation from 40-inch rows was 1.34 times as much as from 20-inch rows.

In the 20-inch rows the soil temperature at a depth of two inches remained uniform across the rows throughout the day. In the 40-inch rows the soil temperature increased toward the center of the rows and also reached a higher maximum temperature than in the 20-inch rows.

The difference in soil temperature between the two different row widths was evident from the surface soil to a depth of at least six inches. At the greater depths the temperature difference decreased.

Air temperatures were lower between the 20-inch rows than between the 40-inch rows as a result of the more effective shading between the narrower rows.

The narrower row spacings also resulted in a slower rate of drying of the surface soil following a period of precipitation. Height of plants was influenced by both area and row width. The narrowest row width and the greatest area per plant resulted in the shortest plants.

Yield of grain was influenced by both row width and plant spacing. Highest yields were obtained from 20-inch and 30-inch

rows with an area of 80 or 100 square inches per plant.

Size of head increased as the area per plant increased. Row width had less effect on size of head than plant spacing.

Size of head was influenced more by the number of kernels per head than by the size of kernel. The 20- and 30-inch rows produced a significantly greater number of kernels per head than the other row widths.

Test weights were well above the 56 pounds per bushel standard in all plots. The highest test weights were associated with the highest yields.

Differences in row width and plant spacing (area per plant) influenced shading, evaporation, soil and air temperatures, drying of surface soil, height of plants, yield of grain, size of heads, and test weights.